

- [54] **METHOD FOR ROTATING A BINARY IMAGE**
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- [52] **U.S. Cl.** ..... 364/900; 382/46
- [58] **Field of Search** ..... 382/46; 340/727, 728; 364/200 MS File, 900 MS File

- [56] **References Cited**
- U.S. PATENT DOCUMENTS**
- |           |        |                  |         |
|-----------|--------|------------------|---------|
| 4,168,488 | 9/1979 | Evans .....      | 340/727 |
| 4,245,321 | 1/1981 | Gennetten .....  | 340/727 |
| 4,267,555 | 5/1981 | Boyd et al. .... | 340/727 |
| 4,271,476 | 6/1981 | Lotspiech .....  | 382/46  |

**OTHER PUBLICATIONS**

Morrin, "Rotation of Images Using Contour Compressed Data", IBM Technical Disclosure Bulletin, vol. 18, #8, Jan. 1976, pp. 2640-2642.

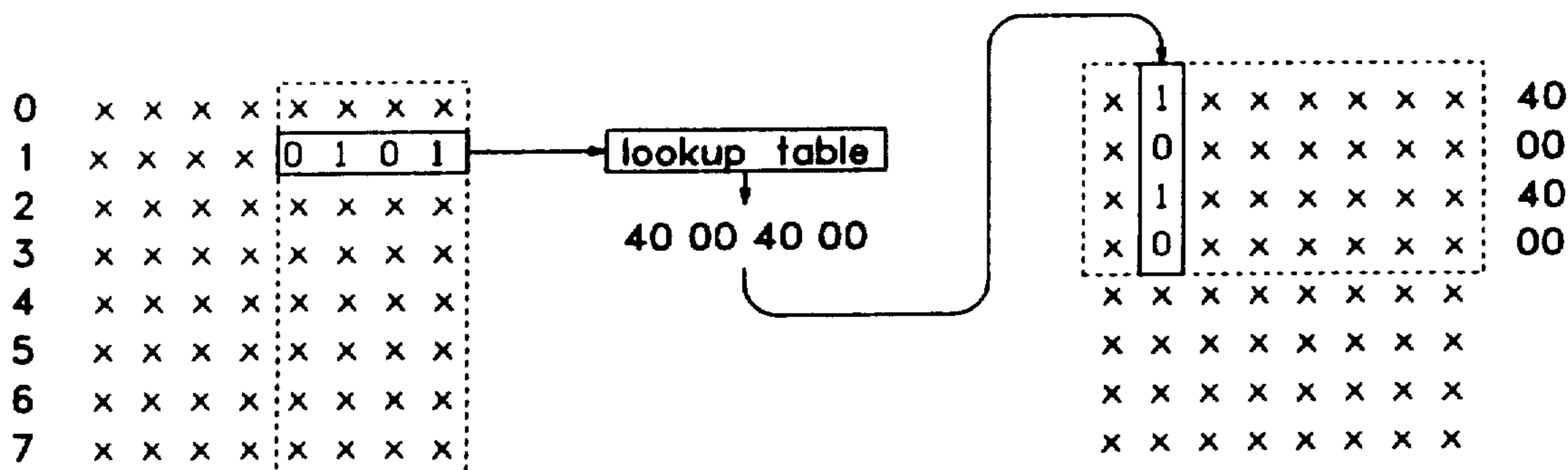
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[57] **ABSTRACT**

A method for rotating an image by 90 degrees includes the steps of: storing the image in a raster format arranged in r rows by c columns, image information in each row being stored in a number of bytes, each byte having b bits, there being c/b bytes in each row of the raster format; moving a block of the image into a temporary storage, there being r rows by v columns in the block; separating each image block into groups of bytes of rotatable size; determining for each group if all bits are the same value; rotating each group that does not have all bits the same value; storing each rotated group in an output area of the raster storage; repeating the above steps for all remaining blocks of the image.

**18 Claims, 8 Drawing Figures**

**8x8 Bit Rotation Calculation for One Nibble**



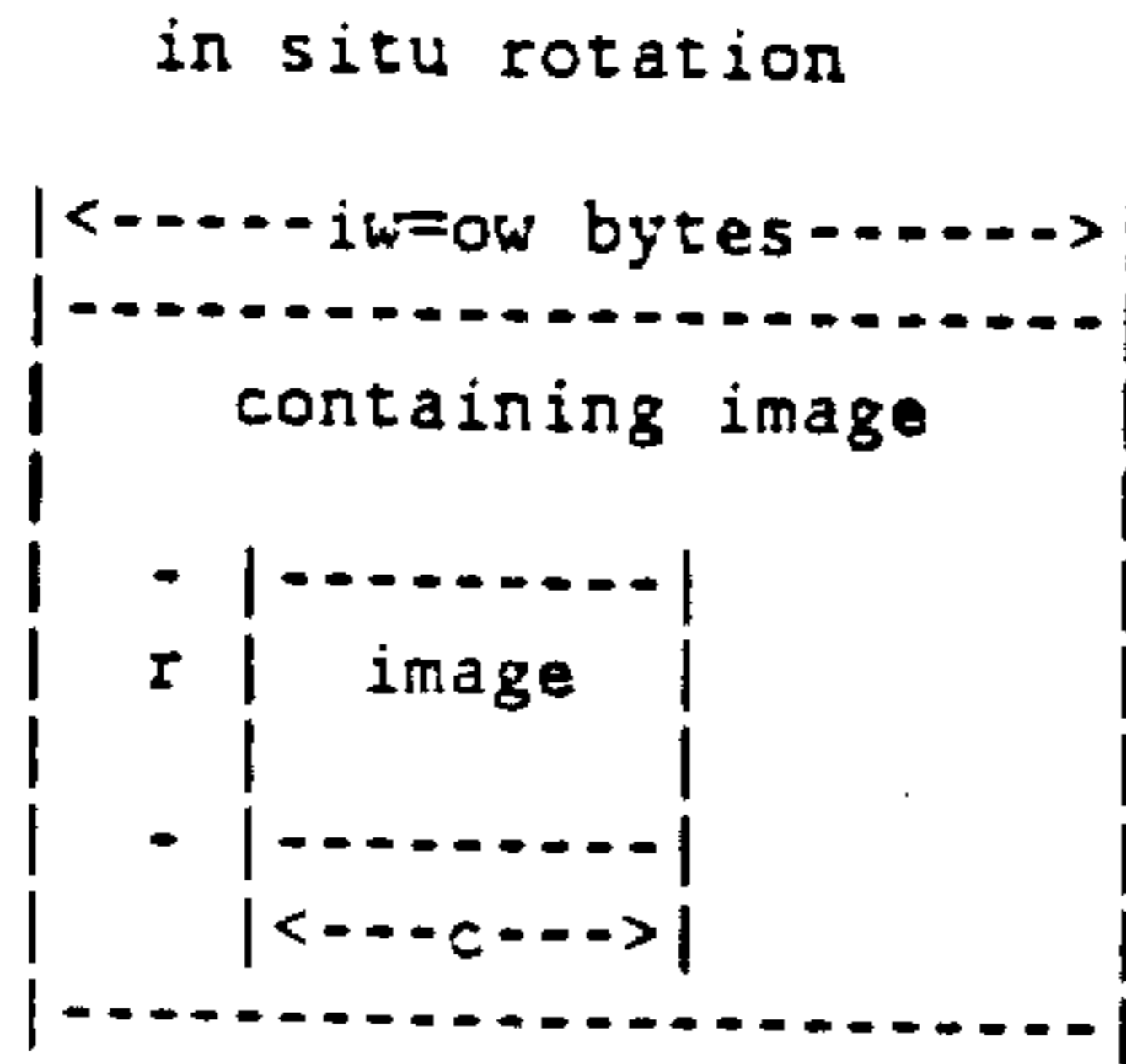


FIG. 1

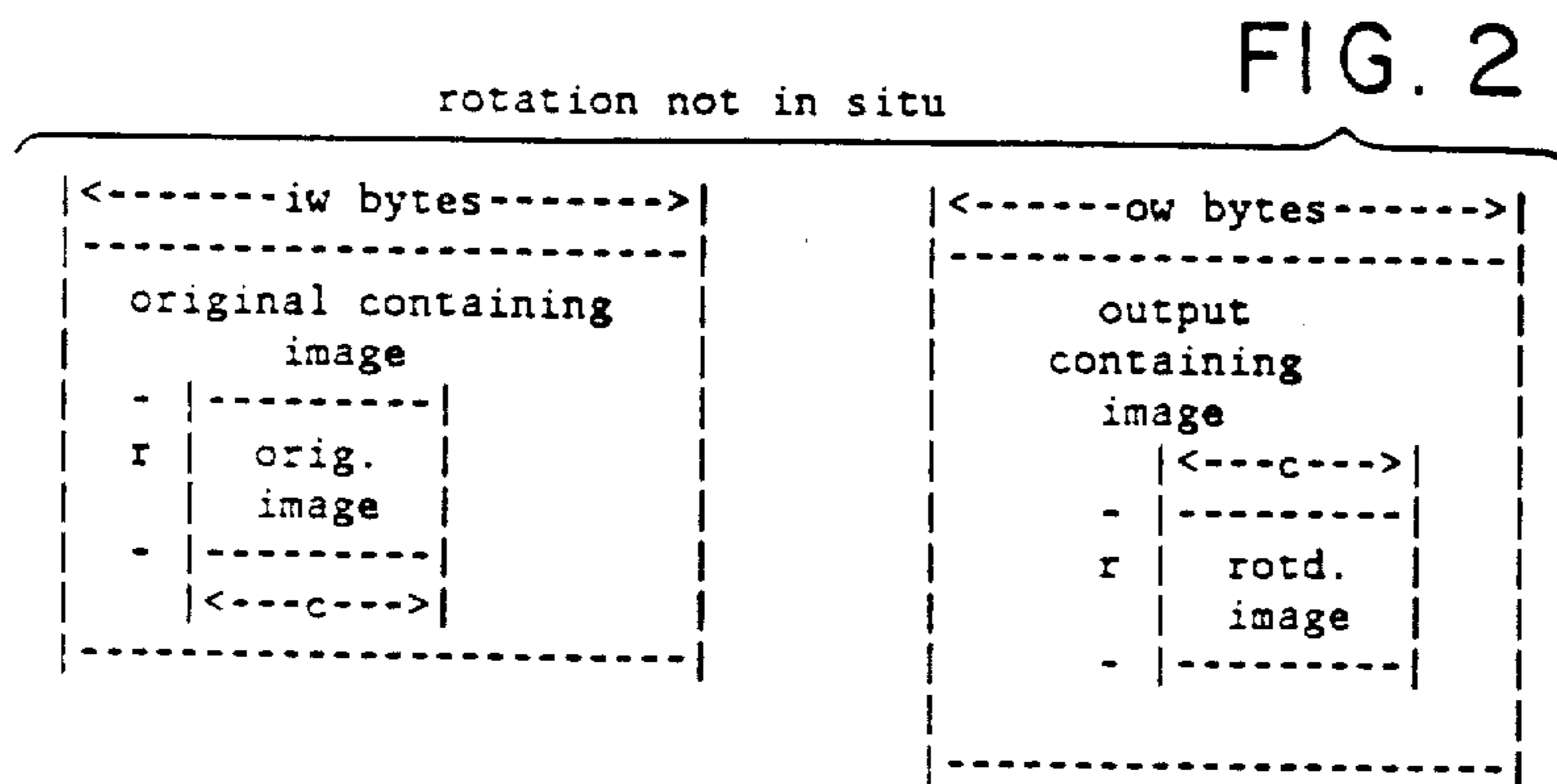


FIG. 2

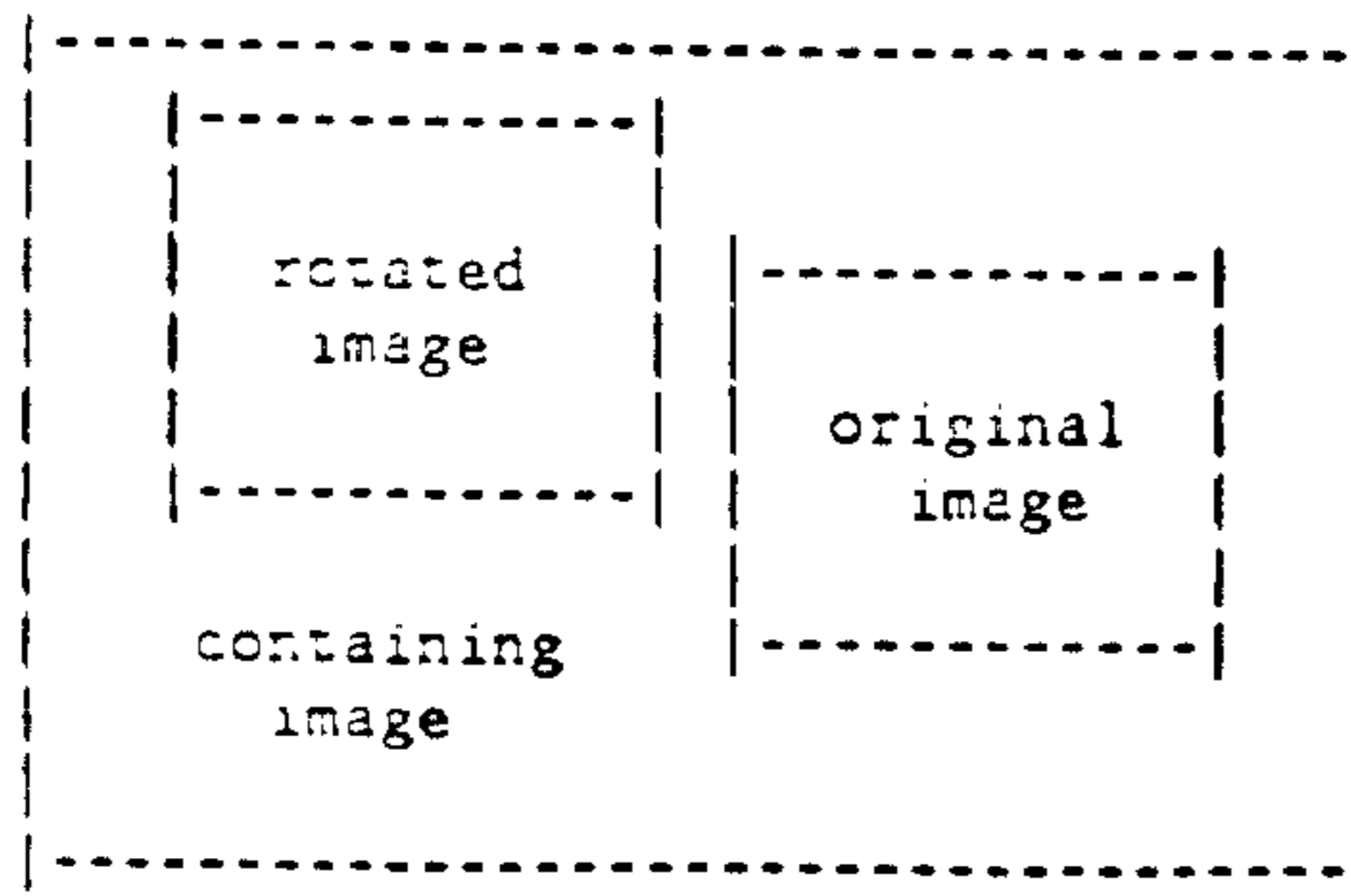


FIG. 3

Byte Rearrangement for Image Rotation

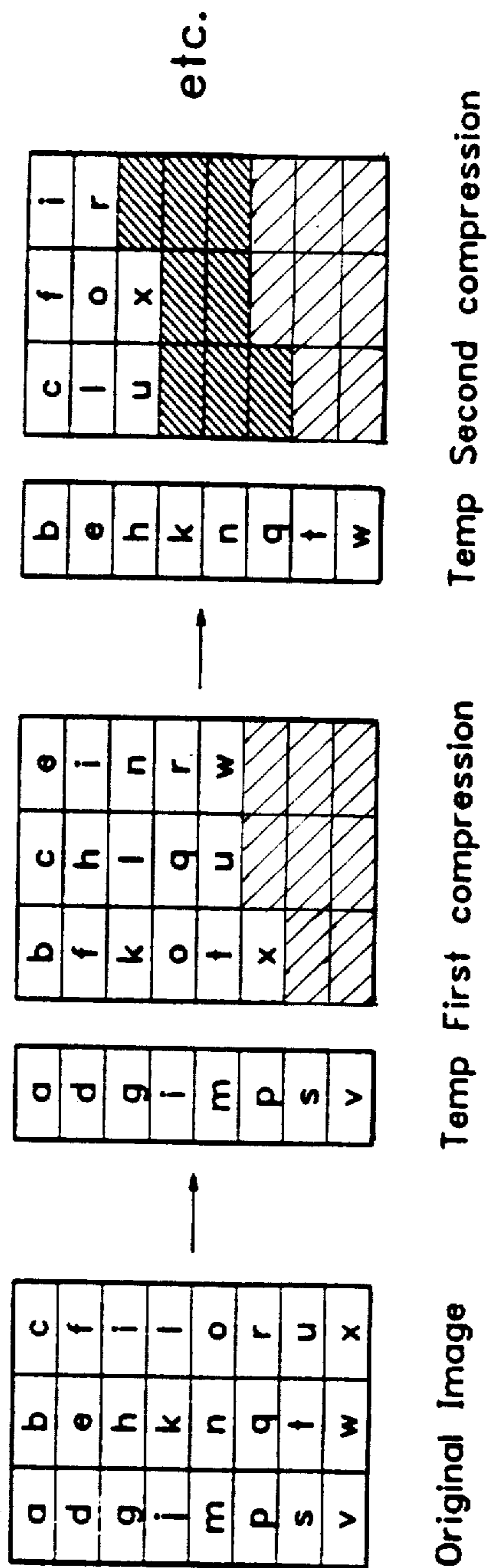


FIG. 4

8x8 Bit Rotation Calculation for One Nibble

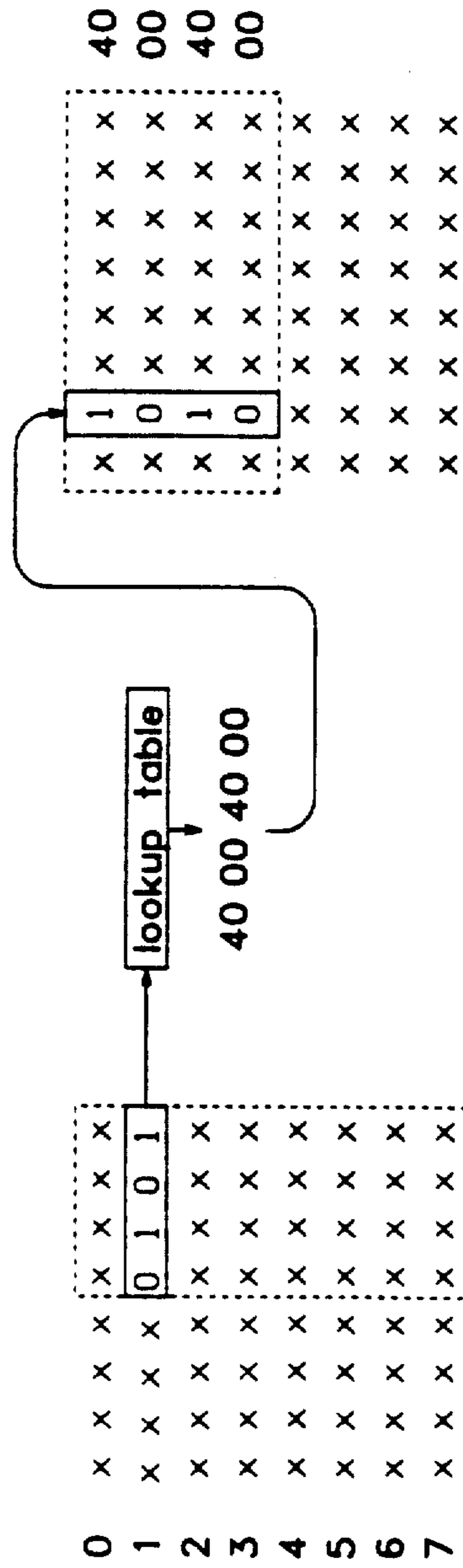


FIG. 5

Lookup Tables for 8x8 Bit Rotation (hexadecimal)

	tbl0	tbl1	tbl2	tbl3
00	00000000	00000000	00000000	00000000
01	80000000	40000000	20000000	10000000
02	00800000	00400000	00200000	00100000
03	80800000	40400000	20200000	10100000
04	00008000	00004000	00002000	00001000
05	80008000	40004000	20002000	10001000
06	00808000	00404000	00202000	00101000
07	80808000	40404000	20202000	10101000
08	00000080	00000040	00000020	00000010
09	80000080	40000040	20000020	10000010
0A	00800080	00400040	00200020	00100010
0B	80800080	40400040	20200020	10100010
0C	00008080	00004040	00002020	00001010
0D	80008080	40004040	20002020	10001010
0E	00808080	00404040	00202020	00101010
0F	80808080	40404040	20202020	10101010

FIG. 6

Lookup Tables for 8x8 Bit Rotation (hexadecimal)

	tbl4	tbl5	tbl6	tbl7
00	00000000	00000000	00000000	00000000
01	08000000	04000000	02000000	01000000
02	00080000	00040000	00020000	00010000
03	08080000	04040000	02020000	01010000
04	00008000	00004000	00002000	00001000
05	08008000	04004000	02002000	01001000
06	00080800	00040400	00020200	00010100
07	08080800	04040400	02020200	01010100
08	00000008	00000004	00000002	00000001
09	08000008	04000004	02000002	01000001
0A	00080008	00040004	00020002	00010001
0B	08080008	04040004	02020002	01010001
0C	00000808	00000404	00000202	00000101
0D	08000808	04000404	02000202	01000101
0E	00080808	00040404	00020202	00010101
0F	08080808	04040404	02020202	01010101

FIG. 7

Rotation of an 8x8 Bit Block

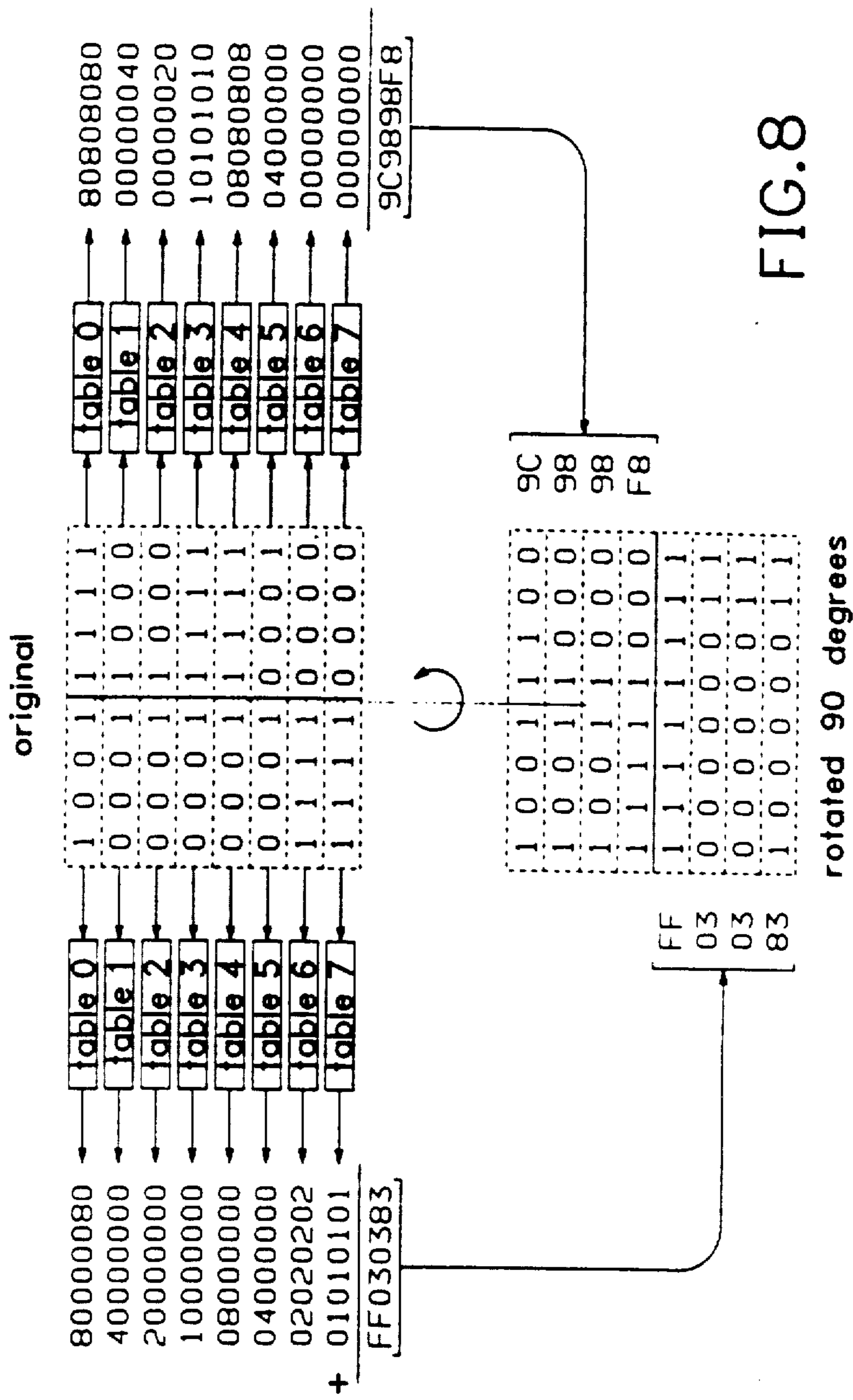


FIG.8

## METHOD FOR ROTATING A BINARY IMAGE

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to digital image processing methods and more particularly to methods for image rotation.

#### 2. Description of the Prior Art

The following are systems representative of the prior art.

U.S. Pat. No. 3,976,872 shows a method of rotation of an image by 90 degrees among other functions performed. However, the patent does not show a method for rotating an image by 90 degrees which includes testing groups of bits in the image to determine whether the group of bits is all the same value as does the present invention.

U.S. Pat. No. 3,968,475 shows a digital processor for extracting data from a binary image in which the image is divided into an array of sample areas each sample area containing an array of binary data spaces. Although the patent demonstrates image rotation by any one of a number of predetermined angles, the patent does not show a method for rotating an image by 90 degrees either clockwise or counterclockwise including testing the sample group to determine if all bits of the sample group are the same as does the method according to the present invention.

U.S. Pat. No. 4,052,699 relates to an image processing system wherein video data is stored in a matrix having  $n$  rows and  $n$  columns. The image is rotated 90 degrees in a piece-meal fashion by vertically accessing word by word video data previously stored as horizontal words. However, the method and apparatus of the patent do not test the group of words to be rotated to determine if all bits in the group are the same as does the method according to the present invention.

U.S. Pat. No. 4,168,488 shows hardware for image rotation of a word organized image buffer where the buffer is divided into a number of square sections each storing a portion of the full image. Although the patent shows apparatus for image rotation through an angle of 90 degrees, the patent does not show a method which includes testing a subimage to determine if all bits in the subimage are the same value as does the method according to the present invention.

U.S. Pat. No. 4,225,929 relates to a code converter including means for rotating an image about a center point. The patent does not include testing of bits in a subimage to determine if all bits are the same as does the method according to the present invention.

U.S. Pat. No. 4,271,476 relates to apparatus for rotating horizontal scan format images into vertical scan format images for printing or other processing. The patented apparatus divides the image into a number of sections and then rotates each section in sequence. The patent does not show a method including testing each section to determine if all bits are the same as does the method according to the present invention.

EPO published patent application no. 081,096 relates to an image rotation control circuit for controlling printing of an image on a printer. The published control circuit does not store the entire display but merely a single line at a time which is converted from a horizontal line to a vertical line or vice versa for printing. The publication does not show a method for rotating an image by 90 degrees including testing a portion of the

image to determine if all bits representing picture elements are the same as does the method according to the present invention.

An article in the IBM Technical Disclosure Bulletin, Vol. 18, No. 8, January 1976, p. 2640 shows a method for rotation of images using contour compressed data. However, the article does not include testing portions of an image to determine if all bits are the same as does the method according to the present invention.

An article in the IBM Technical Disclosure Bulletin, Vol. 13, No. 11, April 1971, p. 3267 shows a method for performing a fast transformation of axes on two dimensional binary images. The article does not include testing portions of an image to determine if all bits are the same as does the method according to the present invention.

An article in the IBM Technical Disclosure Bulletin, Vol. 18, No. 8, January 1976 at page 2633 shows a shift register system for image orientation which among other functions rotates an image in  $4 \times 4$  arrays of characters. The article does not include testing portions of an image to determine if all bits are the same as does the method according to the present invention.

The prior art discussed above does not teach nor suggest the present invention as disclosed and claimed herein.

### SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to rotate an image by a method including the steps of: storing the image in a raster format arranged in  $r$  rows by  $c$  columns, image information in each row being stored in a number of bytes, each byte having  $b$  bits, there being  $c/b$  bytes in each row of the raster format; moving a block of the image into a temporary storage, there being  $r$  rows by  $v$  columns in the block; separating each image block into groups of bytes of rotatable size; determining for each group if all bits are the same value; rotating each group that does not have all bits the same value; storing each rotated group in an output area of the raster storage; repeating the above steps for all remaining blocks of the image.

It is another object of the present invention to rotate an image as above by a method further including the step of: moving remaining bytes to fill the space vacated by the removed image block if the image is to be rotated in situ.

Accordingly, a method for rotating an image by 90 degrees includes the steps of: storing the image in a raster format arranged in  $r$  rows by  $c$  columns, image information in each row being stored in a number of bytes, each byte having  $b$  bits, there being  $c/b$  bytes in each row of the raster format; moving a block of the image into a temporary storage, there being  $r$  rows by  $v$  columns in the block; separating each image block into groups of bytes of rotatable size; determining for each group if all bits are the same value; rotating each group that does not have all bits the same value; storing each rotated group in a output area of the raster storage; repeating the above steps for all remaining blocks of the image.

The foregoing and other objects, features and advantages of the invention will be apparent from the more particular description of the preferred embodiments of the invention, as illustrated in the accompanying drawing.



## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram of in situ rotation according to the present invention.

FIG. 2 is a schematic diagram of not in situ rotation according to the present invention.

FIG. 3 is a schematic diagram of rotation of subimages according to the present invention.

FIG. 4 is a schematic diagram of byte rearrangement for image rotation according to the present invention.

FIG. 5 is a schematic diagram of rotation of a nibble by the method of the present invention.

FIG. 6 is a first group of look up tables for rotation of an  $8 \times 8$  block of an image in accordance with the method of the present invention.

FIG. 7 is a second group of look up tables for rotation of an  $8 \times 8$  block of an image in accordance with the method of the present invention.

FIG. 8 is a diagram of the method for rotating an  $8 \times 8$  bit block in accordance with the method of the present invention.

In the drawing, like elements are designated with similar reference numbers, and identical elements in different specific embodiments are designated by identical reference numbers.

## DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

The method according to the present invention rotates an image clockwise or counterclockwise ninety degrees. Images are considered to exist in storage reading from left to right across the rows, from the top of the image to the bottom. Rotation may be performed in situ, or the output image may occupy separate storage which does not overlap the storage occupied by the original image. It is possible to extract a rectangular portion of a larger image, rotate it, and store it as a portion of another larger image, if desired. The present method performs an in situ rotation if the calling routine supplies the same address for the original and output images; if the output image address is not equal to the original image address, then the rotation is not performed in situ, the input image is not altered by the rotation, and the original and output images are not permitted to overlap. The two basic types of rotation are illustrated in FIG. 1 and FIG. 2.

In the example shown in FIG. 1, the rotated image occupies the storage which contained the original image before rotation. For this type of rotation, the number of rows ( $r$ ) must be a multiple of eight, since the bits in a vertical column are packed into bytes by the rotation and a row of the output image must not end with a fraction of a byte.

In the example of FIG. 2, the original and rotated images occupy separate areas in storage. The original image is not altered by the rotation operation. If the number of rows is not a multiple of eight, the right edge of the rotated image will be filled out to a byte boundary with zeroes. The original and rotated images may not be wider than their respective containing images (although they may be the same width). If the area of storage between the first and last bytes (inclusive) of the original image overlaps the area of storage between the first and last bytes (inclusive) of the output image, the widths of the original and output containing images must be equal.

In the example of FIG. 3, the original and rotated images are assumed to be part of the same containing image.

The program embodying the present invention requires a single parameter PARM which gives the address of a list of six parameters controlling the rotation. These parameters are stored in a 24-byte buffer; all parameters are full 4 byte words. FIXED(31) specifies a 4 byte value; PTR(31) indicates variables which will be addresses. The six parameters are:

DCL	PTR(31); DCL
1 LIST BASED(PARM),	
2 INIMAGE	PTR(31),
2 OUTIMAGE	PTR(31),
2 IROWS	FIXED(31),
2 ICOLS	FIXED(31),
2 IWID	FIXED(31),
2 OWID	FIXED(31);

INIMAGE —Pointer to the first byte (i.e. the upper left-hand corner byte) of the original image.

OUTIMAGE —Pointer to the location where the first byte of the output image is to be stored.

IROWS —Number of lines in the original image. (Corresponds to "r" in FIGS. 1, 2, and 3.)

ICOLS —Number of (byte) columns in the original image. (Corresponds to "c" in FIGS. 1, 2, and 3.)

IWID —Number of (byte) columns in the image of which the original image is a part. If IWID=0, the width of the original image (ICOLS) is substituted for IWID. (IWID corresponds to "iw" in FIGS. 1, 2, and 3.)

OWID —Number of (byte) columns in the image of which the output image is a part. If OWID=0, the width of the output image (the integer quotient of  $(IROWS+7)/8$ ) is substituted for OWID. (OWID corresponds to "ow" in FIGS. 1, 2, and 3.)

The problem considered here is that of rotating a binary image in storage clockwise or counterclockwise by ninety degrees. The rotation algorithm proposed uses a novel combination of techniques (such as a fast rotation algorithm for an eight by eight bit unit and exploitation of the fact that a binary image typically includes large areas containing only zero (white) picture elements) to produce code which is significantly (four to 12 times) faster than current methods.

We describe the counterclockwise case in detail; the required modifications for the clockwise case are summarized at the end of this specification. The bits making up the image are assumed to be stored packed eight to a byte. Since bit operations are computationally expensive, the image is divided into eight by eight bit blocks. The bits in an eight by eight bit block may be rotated relatively efficiently; the blocks are rearranged in storage to complete the rotation process. The image rotation may take place in situ, or the output image may be constructed in an area of storage which does not overlap with the input image.

The block rearrangement for in situ rotation proceeds as illustrated in FIG. 4. The first 32 bytes of each row of the input image are copied into temporary storage. (The number 32 is arbitrary; it controls the amount of temporary storage required to perform the algorithm.) The remaining bytes in each row of the input image are "moved up" in storage, filling in the space left by the removal of the first 32 bytes of each row and leaving a

space at the end of the input image which will accommodate the data from the temporary buffer which must be moved into it. This empty space is cleared (for reasons explained below) and the data from the temporary storage area is rotated and stored in the empty space, producing the last 256 lines of the output image. (Since the rotation of the image is counterclockwise, the data from the left edge moves to the bottom of the image; 32 bytes, or 256 bits, of data was taken from each row, so that 256 lines of output are produced.)

Next, the next 32 bytes from each row are copied into temporary storage, and the remaining data in the rows of the input image are compressed as before. The 256 lines of output image already produced are not disturbed. An empty space now exists immediately before the last 256 lines of the output image; this area is cleared and the data from the temporary buffer are rotated into it.

This process continues until no data is left in the input image. The size of a row of the original image need not be a multiple of 32; if it is not, the last rotation operation acts on only the number of leftover bytes which were in the input image.

If the input and output images do not occupy the same storage, the output image may be cleared before the rotation begins. Successive groups of 32 bytes from each row are copied into temporary storage for processing, but the input image is not compressed after each copy operation; it is left intact. Since the input image does not have to be compressed, this type of rotation is slightly faster than in situ rotation.

Rotation of the bits in the individual eight by eight bit blocks occurs as the data from temporary storage are rotated into their final positions in the output array. The data in the temporary storage area are processed in four-byte-wide columns. (The case in which the number of bytes of data in each row is not a multiple of four is treated separately but the process is essentially the same.) Eight lines of the input image are processed at a time. The basic problem is thus to take a four by eight byte (32 by 8 bit) image, rotate the four eight by eight blocks within it, and position them in the output array.

The first step in the process is to determine whether all of the bits in the 32 by 8 bit block are zero. In this case, no processing is necessary, since the output from the rotation will be a block of zeroes, and the area in the output array where the rotated block would be stored has already been zeroed. Recognizing that no processing is necessary for this case is an important element in gaining speed in the algorithm, since most of the execution time would normally be spent in the rotation of the eight by eight bit blocks, and the case where a 32 by 8 bit block contains entirely of zeroes occurs for from approximately one-third of the image (for kanji or dense text) to over four-fifths of the image (for some drawings and relatively sparse text, e.g. memos).

If a 32 by 8 bit block contains some nonzero bits, it is broken up into four eight by eight bit blocks. Each of these blocks is then checked to see if it consists entirely of zeroes; if it does, it can be skipped as described above. Otherwise the block is rotated using the algorithm illustrated in FIG. 5. This algorithm is described in more detail below. Briefly, the eight bytes are broken up into nibbles, which are used to index into a set of lookup tables shown in FIGS. 6 and 7. These tables are constructed so that when the values looked up for the low- or high-order nibbles are summed, the result gives the first or last four bytes in the rotated block. See FIG. 8.

In addition to rotating an entire image, this algorithm may be used to extract a rectangular portion of one image and rotate it into a rectangular portion of another image. This is done by skipping over the data in the portions of the rows of the input image which are not part of the area to be rotated, and by similarly leaving an appropriate amount of space between the rows of the output image. This type of rotation cannot conveniently be performed in situ by this algorithm; our implementation allows it only when the input and output images are separate.

In order to perform a clockwise rotation, we would simply perform the copy/compress process moving from right to left rather than from left to right (i.e. copy the last 32 bytes from each line into temporary storage at each stage), rotate the data from temporary storage into the output image so that the rightmost (rather than the leftmost) eight by eight bit blocks are rotated to the bottom of the output image, and change the lookup tables used in the rotation of eight by eight bit blocks to produce a clockwise rather than a counterclockwise rotation.

The program embodying the present invention requires an area of storage to contain its variables. These variables are as follows:

Variables in storage shared by all procedures		
name	type	offset from beginning of storage
inimage	PTR(31)	0
inimageb	FIXED(8)	0
outimage	PTR(31)	4
outimageb	FIXED(8)	4
irows	FIXED(32)	8
icols	FIXED(32)	12
iwid	FIXED(32)	16
owid	FIXED(32)	20
etemp	PTR(31)	24
svb	PTR(31)	28
b0ix	PTR(31)	32
b0lim	PTR(31)	36
tindex	PTR(31)	40
p	PTR(31)	44
nccols	FIXED(32)	48
owid2	FIXED(32)	52
owid3	FIXED(32)	56
owid4	FIXED(32)	60
owid5	FIXED(32)	64
owid6	FIXED(32)	68
owid7	FIXED(32)	72
owid8	FIXED(32)	76
ocols	FIXED(32)	80
orows	FIXED(32)	84
tsize	FIXED(32)	88
ttail	FIXED(32)	92
x	FIXED(32)	96
ccols	FIXED(32)	100
bite	FIXED(32)	104
t	FIXED(32)	108
x1(8)	FIXED(8), indexed	112
i11	FIXED(32)	112
i21	FIXED(32)	116
xu(8)	FIXED(8), indexed	120
ilu	FIXED(32)	120
i2u	FIXED(32)	124
whole	FIXED(32)	128
whole0	FIXED(8)	128
whole1	FIXED(8)	129
whole2	FIXED(8)	130
whole3	FIXED(8)	131
w	FIXED(32)	132
wb0	FIXED(8)	132
wb1	FIXED(8)	133

-continued

Variables in storage shared by all procedures		
name	type	offset from beginning of storage
wb2	FIXED(8)	134
wb3	FIXED(8)	135
isflag	FIXED(8)	136
resflag	FIXED(8)	137
lut0(16)	FIXED(32)	140
lut1(16)	FIXED(32)	204
lut2(16)	FIXED(32)	268
lut3(16)	FIXED(32)	332
lut4(16)	FIXED(32)	396
lut5(16)	FIXED(32)	460
lut6(16)	FIXED(32)	524
lut7(16)	FIXED(32)	588
tempbuf(N)	FIXED(32)	652 (N < 64*(irows+7)/8)

Variables based on the pointer "b0"		
name	type	offset from b0
bx(228)	FIXED(8), indexed	0
w0	FIXED(32)	0
w1	FIXED(32)	32
w2	FIXED(32)	64
w3	FIXED(32)	96
w4	FIXED(32)	128
w5	FIXED(32)	160
w6	FIXED(32)	192
w7	FIXED(32)	224

Variable based on the pointer "b1"		
name	type	offset from b1
by(8*owid)	FIXED(8), indexed	0

The lookup tables lut0, lut1, . . . lut7 are initialized with the following hexadecimal values:

lut0:	00000000	80000000	00800000	80800000
	00008000	80008000	00808000	80808000
	00000080	80000080	00800080	80800080
	00008080	80008080	00808080	80808080
lut1:	00000000	40000000	00400000	40400000
	00004000	40004000	00404000	40404000
	00000040	40000040	00400040	40400040
	00004040	40004040	00404040	40404040
lut2:	00000000	20000000	00200000	20200000
	00002000	20002000	00202000	20202000
	00000020	20000020	00200020	20200020
	00002020	20002020	00202020	20202020
lut3:	00000000	10000000	00100000	10100000
	00001000	10001000	00101000	10101000
	00000010	10000010	00100010	10100010
	00001010	10001010	00101010	10101010
lut4:	00000000	08000000	00800000	08080000
	00000800	08000800	00800800	08080800
	00000008	08000008	00800008	08080008
	00000808	08000808	00800808	08080808
lut5:	00000000	04000000	00400000	04040000
	00000400	04000400	00400400	04040400
	00000004	04000004	00400004	04040004
	00000404	04000404	00400404	04040404
lut6:	00000000	02000000	00200000	02020000
	00000200	02000200	00200200	02020200
	00000002	02000002	00200002	02020002
	00000202	02000202	00200202	02020202
lut7:	00000000	01000000	00100000	01010000
	00000100	01000100	00101000	01010100
	00000001	01000001	00100001	01010001
	00000101	01000101	00101001	01010101

Since the language in which this program is written employs forward Polish notation, an end-of-statement symbol (such as the ";" in PL/I) is unnecessary in most cases. Statements may extend over multiple lines.

5 All array indices are expressed as offsets in bytes from the beginning of the array.

The following subroutines are assumed to be available:

```

10 procedure copycompr;
    b0=inimage
    b1=b0
15 nccols=-ccols x
    p=addr tempbuf
20 if nccols>0
    begin
25     if p<etemp
        call copy(p,b1,32)
30     b1=+b1 x
        call copy(b0,b1,nccols)
        b0=+b0 nccols
        b1=+b1 nccols
40     p=+p 32
        repeat
45     end
    end
50 call zero(b0,tsize)
else
55 begin
    if p<etemp
60 call copy(p,b1,32)
        b1=+b1 ccols
        p=+p 32
65 repeat

```

```

end
end
call zero(inimage,*ccols irows)
end
end
procedure copy32;
  b1=inimage
  inimage=+inimage x
  p=addr tempbuf
  begin
    if p<etemp
      call copy(p,b1,32)
      b1=+b1 iwid
      p=+p 32
      repeat
    end
  end
end
if ttail≠0
  call zero(etemp,ttail)
end
end
procedure pr32;
  b0lim=-+addr tempbuf x 256
  b0ix=-addr tempbuf 260
  begin
    b0=+b0ix 4
    if b0<etemp leave end
    b0ix=b0
    b1=tindex
    b1=-b1 sll owid 5
    tindex=b1
  5
  begin
    b0=+b0 256
  10
    if b0<etemp leave end
    b1=+b1 1
  15
    whole=or or or or or or or w0 w1 w2
           w3 w4 w5 w6 w7
    if whole=0
  20
      repeat
    end
  25
    svb=b1
    if whole3=0 goto byte2 end
  30
    wb0=bx(003)
    wb1=bx(035)
  35
    wb2=bx(067)
    wb3=bx(099)
  40
    ill=and X'3C3C3C3C' (sll w 2)
    ilu=and X'3C3C3C3C' (srl w 2)
  45
    wb0=bx(131)
    wb1=bx(163)
    wb2=bx(195)
  50
    wb3=bx(227)
    i2l=and X'3C3C3C3C' (sll w 2)
  55
    i2u=and X'3C3C3C3C' (srl w 2)
    w=++++++lut0(x1(0)) lut1(x1(1))
  60
           lut2(x1(2)) lut3(x1(3))
           lut4(x1(4)) lut5(x1(5))
  65
           lut6(x1(6)) lut7(x1(7))
    by(0) =wb0

```

```

by(owid) =wb1
by(owid2)=wb2
by(owid3)=wb3
w+++++++lut0(xu(0)) lut1(xu(1))
          lut2(xu(2)) lut3(xu(3))
          lut4(xu(4)) lut5(xu(5))
          lut6(xu(6)) lut7(xu(7))

by(owid4)=wb0
by(owid5)=wb1
by(owid6)=wb2
by(owid7)=wb3
label byte2
b1+=b1 owid8

if whole2=0 goto bytel end

wb0=bx(002)
wb1=bx(034)
wb2=bx(066)
wb3=bx(098)

i1l=and X'3C3C3C3C' (s11 w 2)
i1u=and X'3C3C3C3C' (sr1 w 2)

wb0=bx(130)
wb1=bx(162)
wb2=bx(194)
wb3=bx(226)

i2l=and X'3C3C3C3C' (s11 w 2)
i2u=and X'3C3C3C3C' (sr1 w 2)

w+++++++lut0(xl(0)) lut1(xl(1))
          lut2(xl(2)) lut3(xl(3))
          lut4(xl(4)) lut5(xl(5))

```

```

          lut6(xl(6)) lut7(xl(7))
by(0) =wb0
5 by(owid) =wb1
by(owid2)=wb2
10 by(owid3)=wb3
w+++++++lut0(xu(0)) lut1(xu(1))
15 lut2(xu(2)) lut3(xu(3))
          lut4(xu(4)) lut5(xu(5))
20 lut6(xu(6)) lut7(xu(7))

by(owid4)=wb0
25 by(owid5)=wb1
by(owid6)=wb2
30 by(owid7)=wb3
label byte1
35 b1+=b1 owid8
if whole1=0 goto byte0 end
40 wb0=bx(001)
wb1=bx(033)
45 wb2=bx(065)
wb3=bx(097)

i1l=and X'3C3C3C3C' (s11 w 2)
50 i1u=and X'3C3C3C3C' (sr1 w 2)
wb0=bx(129)
55 wb1=bx(161)
wb2=bx(193)
60 wb3=bx(225)

i2l=and X'3C3C3C3C' (s11 w 2)
65 i2u=and X'3C3C3C3C' (sr1 w 2)
w+++++++lut0(xl(0)) lut1(xl(1))

```

```

lut2(x1(2)) lut3(x1(3))
lut4(x1(4)) lut5(x1(5))
lut6(x1(6)) lut7(x1(7))
by(0) =wb0
by(owid) =wb1
by(owid2)=wb2
by(owid3)=wb3
w+++++++lut0(xu(0)) lut1(xu(1))
lut2(xu(2)) lut3(xu(3))
lut4(xu(4)) lut5(xu(5))
lut6(xu(6)) lut7(xu(7))
by(owid4)=wb0
by(owid5)=wb1
by(owid6)=wb2
by(owid7)=wb3
label byte0
if whole0=0
  bl=svb
  repeat
end
bl+=b1 owid8
wb0=bx(000)
wb1=bx(032)
wb2=bx(064)
wb3=bx(096)
i1l=and X'3C3C3C3C' (sll w 2)
ilu=and X'3C3C3C3C' (srl w 2)
wb0=bx(128)
wb1=bx(160)

```

```

wb2=bx(192)
wb3=bx(224)
5
i2l=and X'3C3C3C3C' (sll w 2)
i2u=and X'3C3C3C3C' (srl w 2)
10
w+++++++lut0(x1(0)) lut1(x1(1))
lut2(x1(2)) lut3(x1(3))
15
lut4(x1(4)) lut5(x1(5))
lut6(x1(6)) lut7(x1(7))
20
by(0) =wb0
by(owid) =wb1
25
by(owid2)=wb2
by(owid3)=wb3
30
w+++++++lut0(xu(0)) lut1(xu(1))
lut2(xu(2)) lut3(xu(3))
35
lut4(xu(4)) lut5(xu(5))
lut6(xu(6)) lut7(xu(7))
40
by(owid4)=wb0
by(owid5)=wb1
45
by(owid6)=wb2
by(owid7)=wb3
50
bl=svb
repeat
end
55
repeat
end
60
end
procedure pr32last;
65
b0=+-addr tempbuf 256 x
b1=-outimage 1

```

```

begin
  b0=+b0 256
  if b0<etemp leave end
  h1=+h1 1
  whole=or or or or or or or w0 w1 w2
         w3 w4 w5 w6 w7
  if whole=0
    repeat
  end
  svb=b1

  if resflag llt 3
    if resflag=2
      goto lbytelx
    else
      goto lbyte0x
    end
  end

  if whole2=0 goto lbytel end
  wb0=bx(002)
  wb1=bx(034)
  wb2=bx(066)
  wb3=bx(098)
  i1l=and X'3C3C3C3C' (sll w 2)
  i1u=and X'3C3C3C3C' (srl w 2)
  wb0=bx(130)
  wb1=bx(162)
  wb2=bx(194)
  wb3=bx(226)

```

```

  i2l=and X'3C3C3C3C' (sll w 2)
  i2u=and X'3C3C3C3C' (srl w 2)
5  w=+++++++lut0(xl(0)) lut1(xl(1))
        lut2(xl(2)) lut3(xl(3))
10  lut4(xl(4)) lut5(xl(5))
        lut6(xl(6)) lut7(xl(7))
15  by(0)    =wb0
        by(owid) =wb1
20  by(owid2)=wb2
        by(owid3)=wb3
25  w=+++++++lut0(xu(0)) lut1(xu(1))
        lut2(xu(2)) lut3(xu(3))
30  lut4(xu(4)) lut5(xu(5))
        lut6(xu(6)) lut7(xu(7))
35  by(owid4)=wb0
        by(owid5)=wb1
        by(owid6)=wb2
40  by(owid7)=wb3
  label lbytel
45  b1=+b1 owid8
  label lbytelx
50  if whole1=0 goto lbyte0 end
        wb0=bx(001)
55  wb1=bx(033)
        wb2=bx(065)
60  wb3=bx(097)
        i1l=and X'3C3C3C3C' (sll w 2)
65  i1u=and X'3C3C3C3C' (srl w 2)
        wb0=bx(129)

```

```

wb1=bx(161)
wb2=bx(193)
wb3=bx(225)
i2l=and X'3C3C3C3C' (sll w 2)
i2u=and X'3C3C3C3C' (srl w 2)
w=+++++++lut0(xl(0)) lut1(xl(1))
          lut2(xl(2)) lut3(xl(3))
          lut4(xl(4)) lut5(xl(5))
          lut6(xl(6)) lut7(xl(7))
by(0)    =wb0
by(owid) =wb1
by(owid2)=wb2
by(owid3)=wb3
w=+++++++lut0(xu(0)) lut1(xu(1))
          lut2(xu(2)) lut3(xu(3))
          lut4(xu(4)) lut5(xu(5))
          lut6(xu(6)) lut7(xu(7))
by(owid4)=wb0
by(owid5)=wb1
by(owid6)=wb2
by(owid7)=wb3
label lbyte0
if whole0=0
    bl=svb
    repeat
end
bl+=b1 owid8
label lbyte0x

```

```

wb0=bx(000)
wb1=bx(032)
5  wb2=bx(064)
   wb3=bx(096)
10 i1l=and X'3C3C3C3C' (sll w 2)
   i1u=and X'3C3C3C3C' (srl w 2)
15 wb0=bx(128)
   wb1=bx(160)
20 wb2=bx(192)
   wb3=bx(224)
25 i2l=and X'3C3C3C3C' (sll w 2)
   i2u=and X'3C3C3C3C' (srl w 2)
30 w=+++++++lut0(xl(0)) lut1(xl(1))
          lut2(xl(2)) lut3(xl(3))
          lut4(xl(4)) lut5(xl(5))
          lut6(xl(6)) lut7(xl(7))
35
40 by(0)    =wb0
   by(owid) =wb1
   by(owid2)=wb2
45   by(owid3)=wb3
   w=+++++++lut0(xu(0)) lut1(xu(1))
          lut2(xu(2)) lut3(xu(3))
          lut4(xu(4)) lut5(xu(5))
          lut6(xu(6)) lut7(xu(7))
55
60 by(owid4)=wb0
   by(owid5)=wb1
   by(owid6)=wb2
65   by(owid7)=wb3
   bl=svb

```



```

repeat
end
end
procedure turn90cc(argpt);
("argpt" gives the address of the
argument buffer)
call copy(addr inimage, argpt, 24)
inimageb=0
outimageb=0
orows=sll icols 3
ocols=sra +irows 7 3
if iwid=0
    iwid=icols
end
if owid=0
    owid=ocols
end
if outimage=inimage
    isflag=1
else
    isflag=0
    ttail=sll -sll ocols 3 irows 5
    b0=outimage
    if owid=ocols
        call zero(b0,*ocols orows)
    else
        t=orows
        begin
            if t->0 leave end
            call zero(b0,ocols)

```

```

    b0=+b0 owid
    t=-t 1
5
    repeat
        end
10
    end
    end
15
    tsize=sll irows 5
    ccols=icols
20
    tindex=-+outimage *owid orows 1
    etemp=+addr tempbuf tsize
25
    owid2=*owid 2
    owid3=*owid 3
30
    owid4=*owid 4
    owid5=*owid 5
35
    owid6=*owid 6
    owid7=*owid 7
40
    owid8=*owid 8
    resflag=0
45
    begin
        if ccols=0 leave end
        if ccols>32
50
            x=32
        else
55
            x=ccols
        end
60
        if isflag=1
            call copycompr
65
        else
            call copy32

```

```

end
resflag=expl and x 3
x=and x _4
if x≠0
    call pr32
end
if resflag≠0
    call pr32last
    leave
end
ccols=-ccols x
repeat
end
end

```

Thus, while the invention has been described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the scope of the invention.

What is claimed is:

1. A method for rotating a binary image in place by 90 degrees comprising the steps of:
  - storing said image in raster form as a sequence of bytes in an image buffer, said bytes representing said image in the form of  $r$  rows by  $c$  columns and each byte having  $b$  bits;
  - dividing said image vertically into a series of blocks, each block having  $r$  rows;
  - copying one block of said image bytes into a temporary storage buffer;
  - rearranging the uncopied bytes in the image buffer to make available a region having an area equal to that of the copied block and at the location in the image buffer where said copied block will fit after rotation, by overwriting a portion of the copied image bytes with uncopied image bytes;
  - separating said copied bytes in said temporary storage buffer into groups of  $m \times m$  bits for rotation;
  - transferring each group to the available region of the image buffer, such that said groups are stored in rotated raster form; repeating said steps of copying, rearranging, separating, and transferring on the successive blocks of said uncopied image bytes to store said image in said image buffer in rotated form.
2. A method as in claim 1 wherein said transferring step comprises:
  - determining for each said group if all bits have the same value;

- copying each group having all bits the same value to the appropriate location in said available region of said image buffer;
  - rotating each group that does not have all bits the same value; and storing each rotated group with said copied groups in raster form in the appropriate location in said available region of said image buffer.
- 3. A method as in claim 2 wherein said rotating step comprises the further steps of:
  - creating a lookup table which takes an index value and produces an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero;
  - dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup table;
  - applying each said subunit as an index to said lookup table;
  - shifting the resulting output values according to the position of the index subunit in the group of bits to be rotated;
  - combining the shifted output values; and
  - storing the resulting bits as a rotated  $m \times m$  bit block.
- 4. A method as in claim 1 wherein said transferring step comprises:
  - filling said available region of said image buffer with bits of a first binary value;
  - determining for each said group if all bits have said first binary value;
  - rotating each group that does not have all bits of said first binary value; and
  - storing each rotated group in raster form in the appropriate location in said available region of said image buffer.
- 5. A method as in claim 4 wherein said rotating step comprises the further steps of:
  - creating a lookup table which takes an index value and produces an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero;
  - dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup table;
  - applying each said subunit as an index to said lookup table;
  - shifting the resulting output values according to the position of the index subunit in the group of bits to be rotated;
  - combining the shifted output values; and
  - storing the resulting bits as a rotated  $m \times m$  bit block.
- 6. A method as in claim 1 wherein  $r$  equals  $c$ .
- 7. A method as in claim 1 wherein  $b$  equals 8 and said groups comprise 8 by 8 bit blocks.
- 8. A method as in claim 2 wherein said rotating step comprises the steps of:
  - creating a plurality of lookup tables which take an index value and produce an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero, and shifted by differing numbers of bits;
  - dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup tables;
  - applying each said subunit as an index to one of said lookup tables, the table used in each case being determined by the position of the index subunit in

the group of bits to be rotated;  
 combining the shifted output values; and  
 storing the resulting bits as a rotated  $m \times m$  bit block.

9. A method as in claim 4 wherein said rotating step comprises the steps of:

creating a plurality of lookup tables which take an index value and produce an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero, and shifted by differing numbers of bits;

dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup tables;

applying each said subunit as an index to one of said lookup tables, the table used in each case being determined by the position of the index subunit in the group of bits to be rotated;

combining the shifted output values; and  
 storing the resulting bits as a rotated  $m \times m$  bit block.

10. A system for rotating a binary image by 90 degrees in place comprising:

image buffer means for storing said image in raster form as a sequence of bytes, said bytes representing said image in the form of  $r$  rows by  $c$  columns and each byte having  $b$  bits;

means for dividing said image vertically into a series of blocks, each block having  $r$  rows;

a temporary storage buffer;

means for copying one block of said image bytes into said temporary storage buffer;

means for rearranging the uncopied bytes in said image buffer means to make available a region of the image buffer means, having an area equal to that of the copied block and at the location in the image buffer means where said copied block will fit after rotation; by overwriting a portion of the copied image bytes with uncopied image bytes;

means for separating said copied bytes in said temporary storage buffer into groups of  $m \times m$  bits for rotation;

means for transferring each group from said temporary storage buffer to the available region of the image buffer means, such that said groups are stored in rotated raster form in said region; and

means for actuating said copying, rearranging, separating, and transferring means to act on the successive blocks of said uncopied image bytes to rotate said stored image in said image buffer means.

11. A system as in claim 10 wherein said transferring means comprises:

means for determining for each said group if all bits have the same value;

means for copying each group having all bits the same value to the appropriate location in said available region of said image buffer means;

means for rotating each group that does not have all bits the same value; and

means for transferring each rotated group to storage with said copied groups in raster form in the appropriate location in said available region of said image buffer means.

12. A system as in claim 11 wherein said rotating means comprises

a lookup table which takes an index value and produces an output consisting of the bits of the index

value spaced at intervals of  $m$  bits, separated by bits having the value zero;

means for dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup table;

means for applying each said subunit as an index to said lookup table;

means for shifting the resulting output values according to the position of the index subunit in the group of bits to be rotated;

means for combining the shifted output values; and  
 means for storing the resulting bits as a rotated  $m \times m$  bit block.

13. A system as in claim 11 wherein said rotating means comprises:

means for creating a plurality of lookup tables which take an index value and produce an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero, and shifted by differing numbers of bits;

means for dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup table means;

means for applying each of said subunits as an index to said lookup table means in accordance with the respective position of the index subunit in the group of bits to be rotated;

means for combining the shifted output values; and  
 means for storing the resulting bits as a rotated  $m \times m$  bit block.

14. A system as in claim 10 wherein said transferring means comprises:

means for filling said available region of said image buffer with bits of a first binary value;

means for determining for each said group if all bits have said first binary value;

means for rotating each group that does not have all bits of said first binary value; and

means for storing each rotated group in raster form in the appropriate location in said available region of said image buffer.

15. A system as in claim 14 wherein said rotating means comprises:

lookup table means for taking an index value and producing an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero;

means for dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup table means;

means for applying each said subunit as an index to said lookup table means;

means for shifting the resulting output values according to the position of the index subunit in the group of bits to be rotated;

means for combining the shifted output values; and  
 means for storing the resulting bits as a rotated  $m \times m$  bit block.

16. A system as in claim 14 wherein said rotating means comprises:

means for creating a plurality of lookup tables which take an index value and produce an output consisting of the bits of the index value spaced at intervals of  $m$  bits, separated by bits having the value zero, and shifted by differing numbers of bits;

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means for dividing said  $m \times m$  group of bits to be rotated into subunits of equal size for use in indexing said lookup table means;  
means for applying each of said subunits as an index to said lookup table means in accordance with the respective position of the index subunit in the group of bits to be rotated;

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means for combining the shifted output values; and means for storing the resulting bits as a rotated  $m \times m$  bit block.

17. A system as in claim 10 wherein  $r$  equals  $c$ .

18. A system as in claim 10 wherein  $n$  equals 8 and said groups comprise 8 by 8 bit blocks.

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